

Advanced Composites Office Supporting Salt Lake Winter Olympics Athletes



The Advanced Composites Office (ACO) manufactured two graphite/epoxy Olympic skeleton prototype sleds for the USAF-sponsored Olympic athletes participating in the Air Force World Class Athlete Program (WCAP) and competing at the World Championship, World Cup, and ultimately at the 2002 Salt Lake City Winter Olympics. The purpose of the project was to demonstrate that the graphite/epoxy sled due to its high-strength and diagonally-tailored torsional stiffness characteristics can improve the skeleton sled's controllability by the athlete, allowing him to better follow the optimal path down the track, possibly resulting in better run times. In addition to the improved controllability, the composite material fabrication process allows the engineers to design and manufacture a sled that is aerodynamically favorable to the traditional aluminum or thermoplastic designs by producing less air resistance (drag) and optimal downward lift (down-force). While minimizing drag is always desirable, finding the optimal down-force is accomplished by the close collaboration of the engineers and the skeleton sled athletes.

Skeleton sleds differ from the better known luge sleds, as the athletes race down the ice track head first, laying flat on their stomachs within inches from the ice. Race speeds can reach up to 85 mph. Compared to bobsleds and luge – where racers steer their way down the track using skates and body positioning respectively – skeleton racers steer their sleds primarily by applying differential shoulder and leg pressures to the sled. By having a sled that has minimum drag and generates optimal down-force while possessing adequate structural strength yet is still flexible within reasonable limits, the athletes can achieve increased responsiveness and improved controllability. Composite materials are ideal candidates for structures like these, where the engineer has to independently tailor the material to the required strength and desired stiffness without having to compromise weight or aerodynamic performance.

In order to gain insight into the flow conditions around the two sleds, and to compare and evaluate aerodynamic performance, the two prototype sleds were aerodynamically tested using computational fluid dynamics (CFD) simulations at the Air Force Research Laboratory, Air Vehicles Directorate, Computational Sciences Branch (VAAC). The computational analyses were necessary in order to predict the down-force and drag generated by the sleds in their nominal (no driver, zero angle of attack) configuration. First, the ACO constructed the computer models of the two sleds on a ProEngineer2000i solid modeling package, then VAAC imported the models into the grid generation preprocessor *GridTool*. The CFD grid was then generated using *VGRID*. The simulations for both sleds were run using the *Cobalt₆₀* flow solver for several thousands of iterations until a converged steady-state solution was achieved. The results were tabulated to find the exact values of lift, drag and sideforce, and the flow field was plotted to help visualize the pressure coefficient-, and velocity distribution along the entire length of both sleds.

The pressure coefficient distribution over the bottom surface of the low-cambered sled is shown by the different colors in Figure 1. The color scale at the upper right-hand corner represents the magnitude of the local non-dimensional coefficient. Figures 2 and 3 show the velocity vector field at the nose section of the low-cambered sled, with the highest velocities shown in pink, the slowest velocities shown in dark blue. Figure 4 depicts the entire velocity distribution in solid colors over the full length of the low-cambered sled. The free-stream velocities are shown in red, higher velocities are pink, and white, while lower velocities are depicted in yellow, green, and blue.

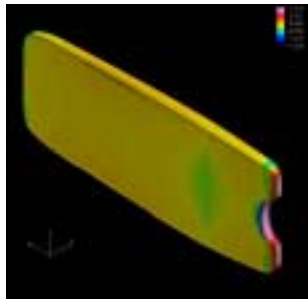


Fig. 1

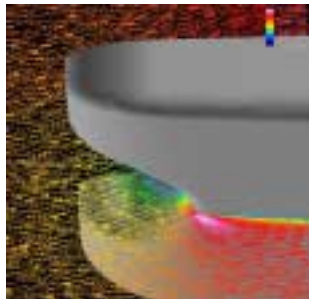


Fig. 2

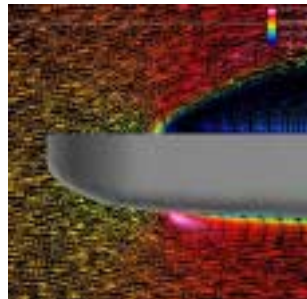


Fig. 3

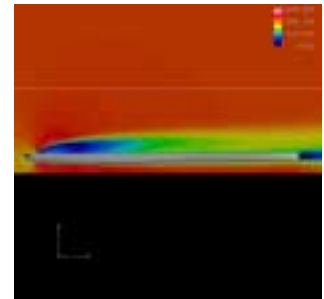


Fig. 4

Figures 5 through 8 represent the same flow-field variables around the high-cambered sled. In Figure 5, the streamlines were added to help better visualize the airflow around the bottom of the high-cambered sled.

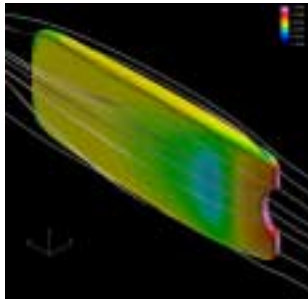


Fig. 5

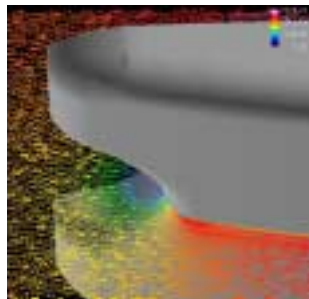


Fig. 6

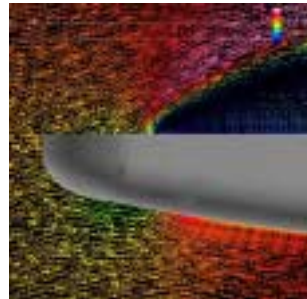


Fig. 7

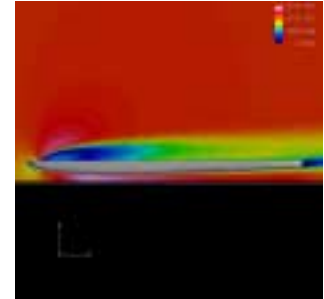


Fig. 8

The exact numerical results of the CFD simulations for the high-cambered sled resulted in a down-force and drag force of 8.13 lb and 2.26 lb respectively. The results for the low-cambered sled were 4.93 lb and 1.90 lb of down-force and drag respectively. The two sleds were designed to produce significantly different lift and drag forces, they had to be tested by the racers on the ice track to find out which one is actually preferable to the other.

Two skeleton sled Olympic athletes, sponsored by the USAF tested the two sleds for suitability, controllability as well as speed at the Park City Olympic Bobsled and Luge track in Utah during the winter of 2000. Interestingly, both racers preferred the low-cambered sled that had less down-force and lower drag as it proved to be more responsive, easier to steer, and most importantly, slightly faster. These test results were exactly the opposite of the engineers' original expectation that the high-cambered sled will prove superior in performance.

The findings of the CFD simulations combined with the outcome of the test runs on the ice-track will serve as the basis for future design and composite sled manufacturing tasks related to the sponsoring of the USAF Olympic athletes.

The Olympic skeleton sled project was beneficial for the ACO, AFRL, and for the WCAP Olympic athletes as it provided valuable hands-on composite manufacturing training and experience for new ACO engineers, it initiated and fueled coordination and collaboration between two distinctively different AFRL organizations, and provided high-value, high-performance assets for the Olympic athletes that otherwise would not have been available to them.

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